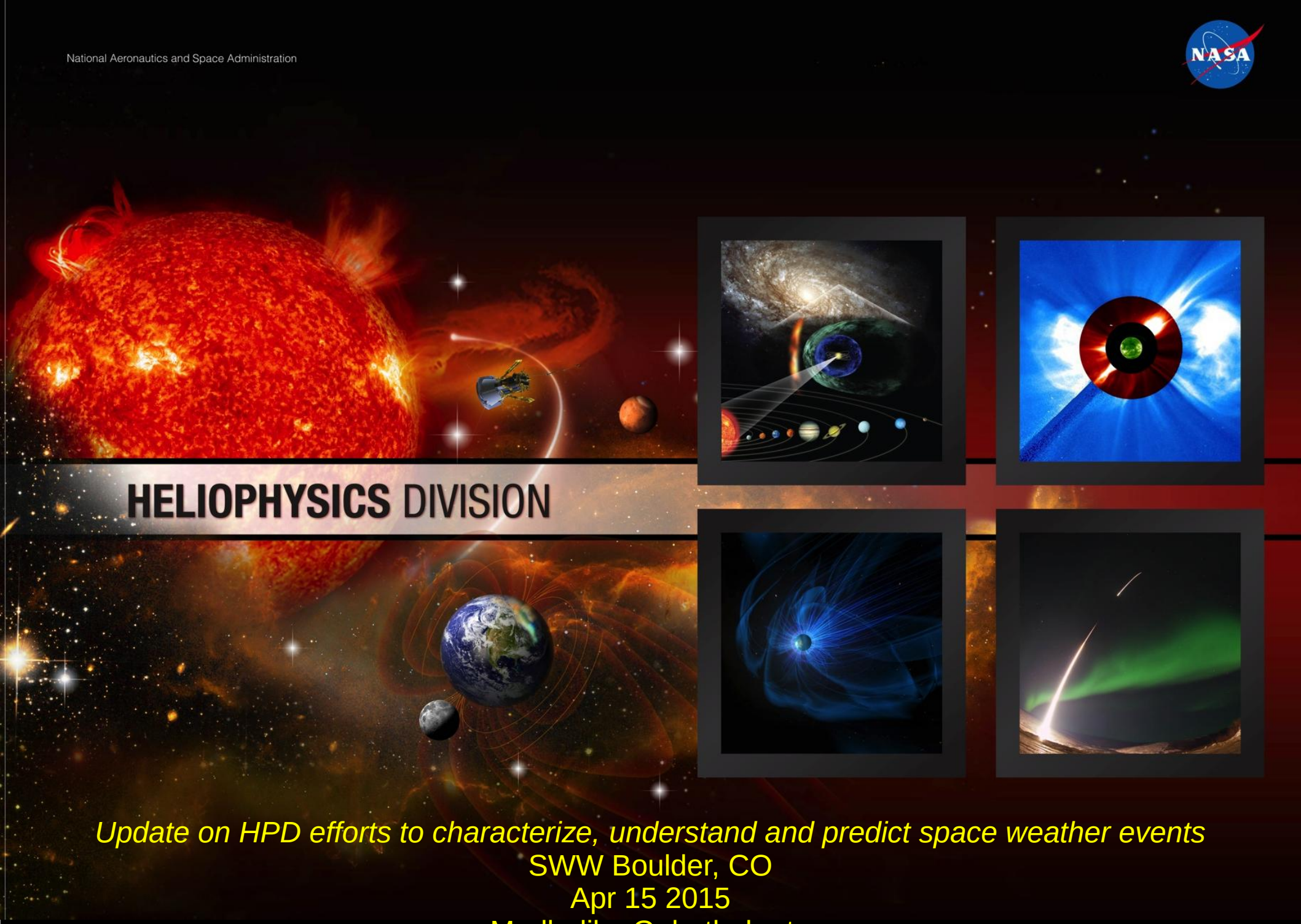
National Aeronautics and Space Administration



HELIOPHYSICS DIVISION

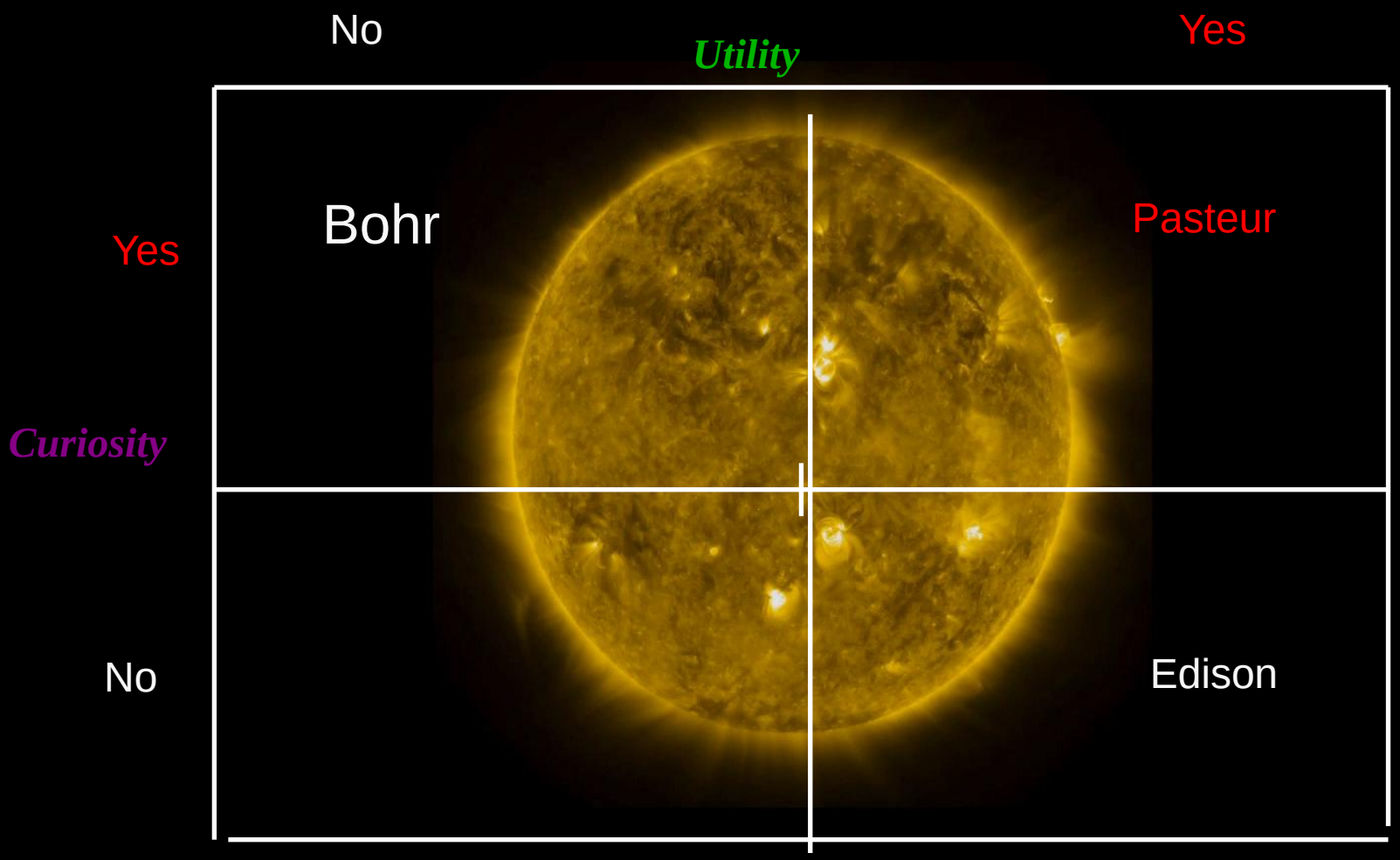
Update on HPD efforts to characterize, understand and predict space weather events

SWW Boulder, CO

Apr 15 2015

Madhulika Guhathakurta

Why Do Science?



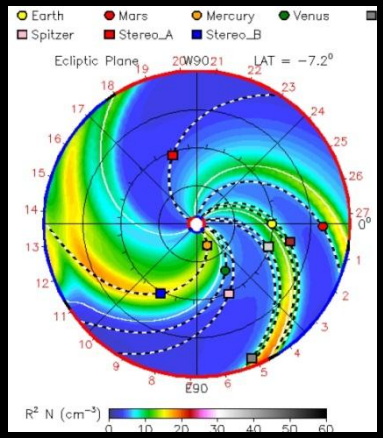
Understanding the Sun and its interactions with the Earth and the Solar System.

Solve fundamental mysteries of Heliophysics
Understand the nature of our home in space
Build the knowledge to forecast space weather throughout the heliosphere

What is Heliophysics

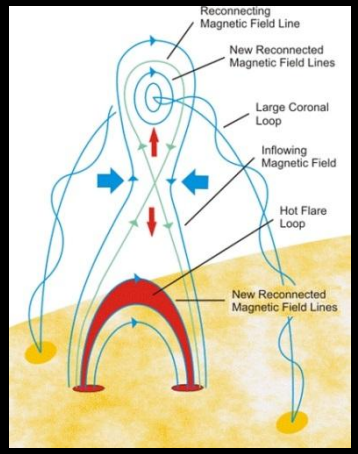
Heliophysics is an environmental science:
a unique hybrid between meteorology and astrophysics

It has an applied branch
space weather



Propagation models of solar disturbances out to 2 AU

And a pure branch
fundamental physical process



Magnetic reconnection

In the US National Space Weather Program 1995

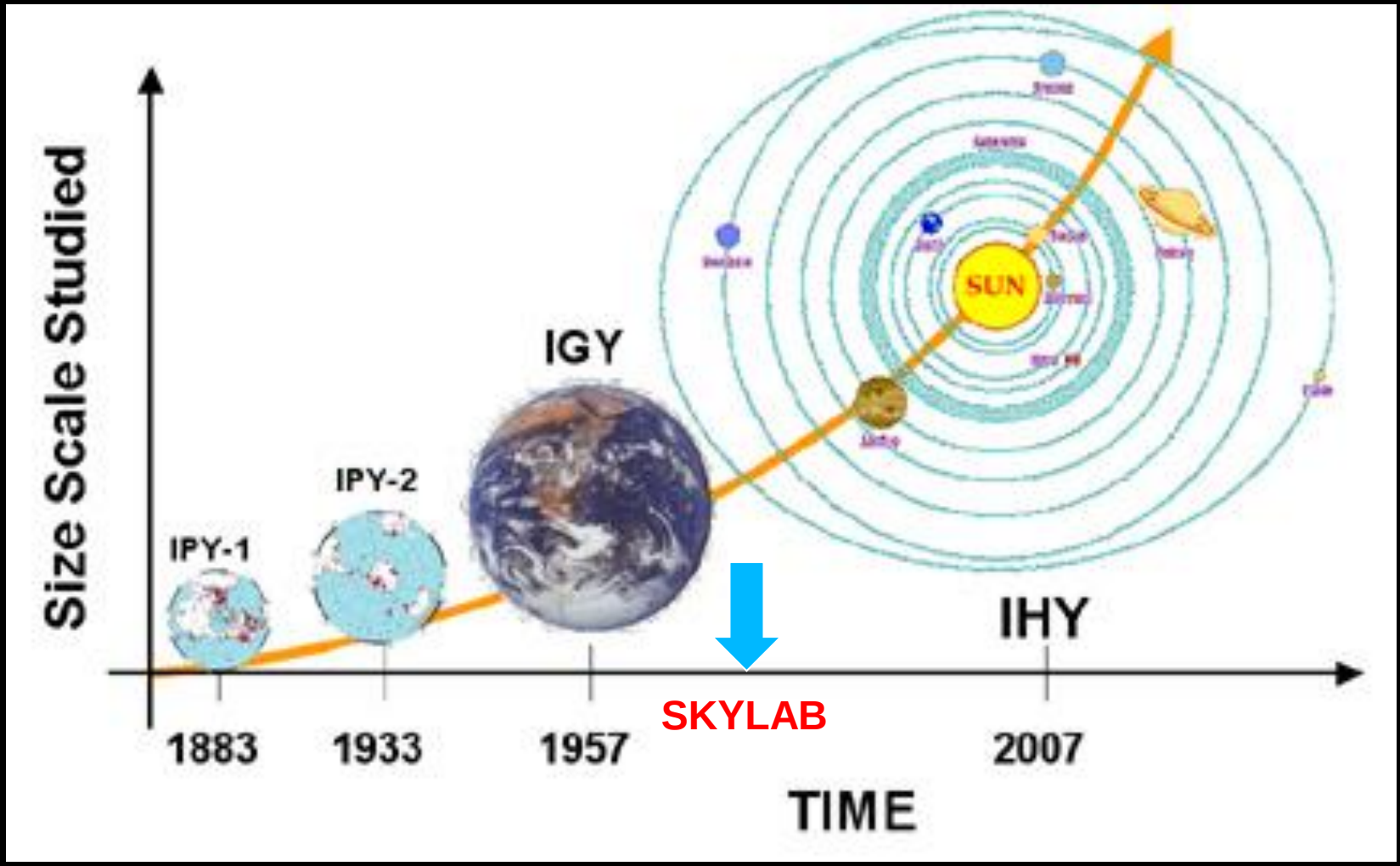
Living With a Star 2000, ILWS 2003

International Heliosphysical Year 2007

Applications directed science coordinated by NASA & international community

And comparative heliospheric studies

Evolution of System Studies

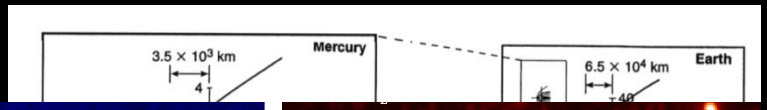


Heliophysical: A broadening of the concept "geophysical," extending the connections from the Earth to the Sun & interplanetary space.

Sun-Earth System Science: Growth from a “consuming” science to a “producing” science for the benefit of humankind

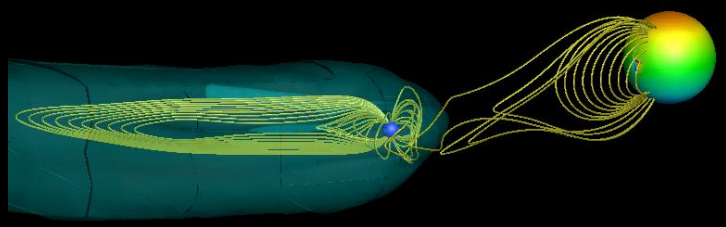
Space Weather is no longer the domain of Earth only!

Space Weather is now also Interplanetary!!



Space Weather just became Exopla

Extreme Space Weat



SkyLab Heliophysics GAME CHANGERS

The Corona is hot and controlled by magnetic fields

➔ X-Ray and EUV Variability at Earth **(NOAA R-Scale)**

High-Speed Solar Wind originates from coronal holes

➔ Solar Particles Impact Earth **(NOAA S-Scale)**

Mass from the corona is ejected into interplanetary space

➔ Solar catastrophic events can impact Earth's magnetosphere **(NOAA G-Scale)**

HPD is Organized into Four Major Sections

Goal: Understand the Sun and its interactions with Earth and the solar system including space weather

Living With a Star

Goal Oriented Strategic Program that is Relevant to Life and Society (space weather)

Solar Terrestrial Probes

Curiosity Driven Strategic Mission Flight Programs (fundamental physics)

Solve the <u>fundamental physics</u> mysteries of heliophysics: Explore and examine the physical processes in the space environment from the sun to the Earth and throughout the solar system.

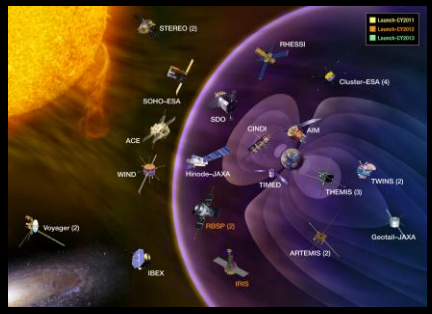
Build the knowledge to forecast space weather throughout the heliosphere: Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Understand the nature of our home in space: Advance our understanding of the connections that link the sun, the Earth, planetary space environments, and the outer reaches of our solar system

Explorers

Smaller flight programs, competed science topics, often PI-led

Research



Scientific research projects utilizing existing data plus theory and modeling

Heliophysics System Observatory

A coordinated and complementary fleet of spacecraft to understand the Sun and its interactions with Earth and the solar system

Heliophysics has 19 operating missions (on 33 spacecraft): Voyager, Geotail, Wind, SOHO ACE Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO THEMIS/ARTEMIS, AIM, CINDI, IBEX, SDO Van Allen Probes IRIS, MMS

(Missions in red contribute to operational Space Weather.)

5missions are in various phases of development: SET, SOC, SPP, ICON, and GOLD

$5.5B total investment in Heliophysics space assets (excluding launch costs)$68M annual operating budget (1.2% per year)

Looking Forward: New HSO Components

Addition of new HSO component where each component need not carry a comprehensive payload

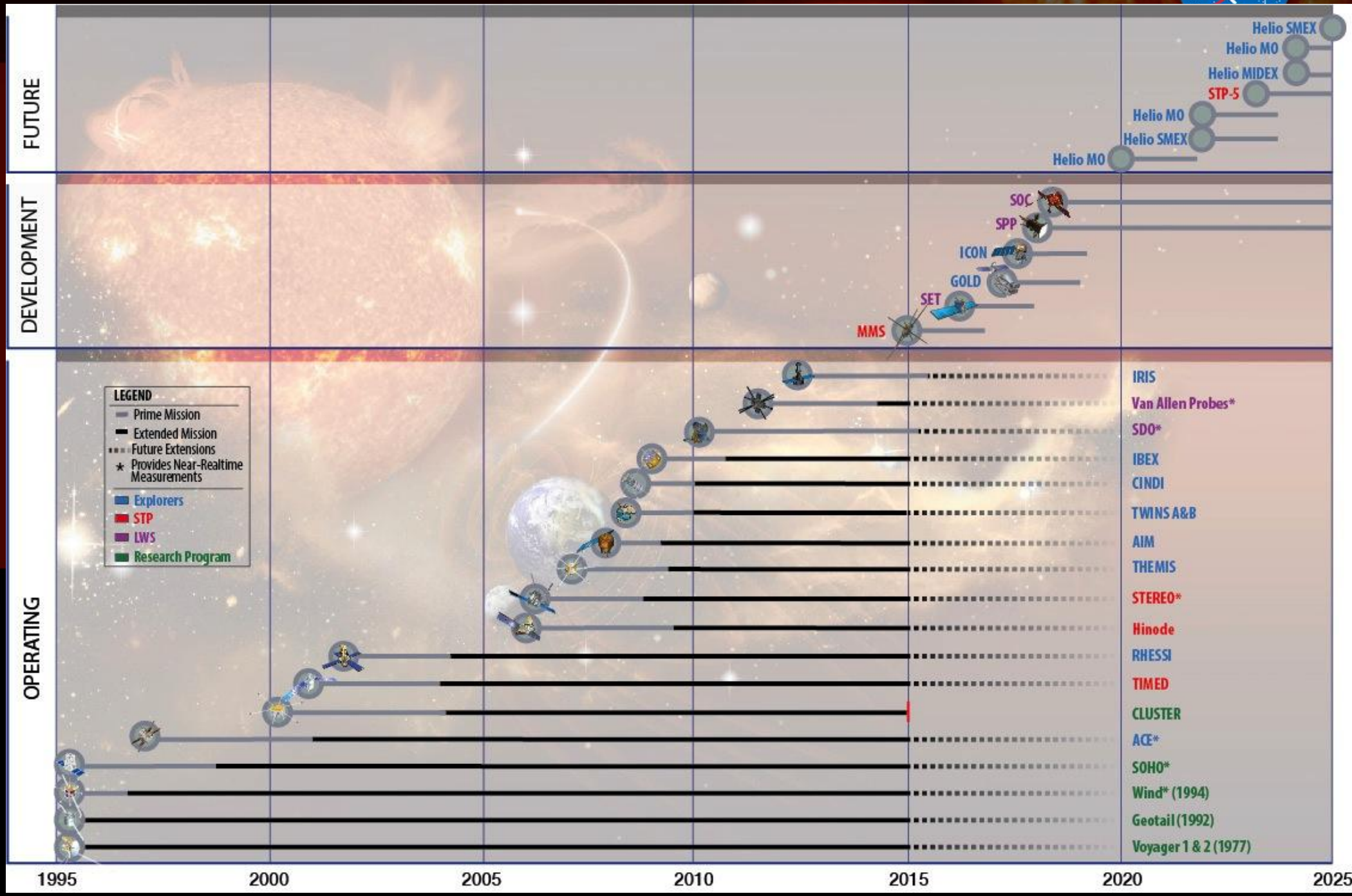
- The network can grow serendipitously, with key measurements made on distributed platforms
- Single instrument MOOs
- Cubesats dedicated to one or two instruments
- Individual measurement sets add value by complementing the existing network

In addition, we need techniques to assess the value of additional components to the HSO as a whole

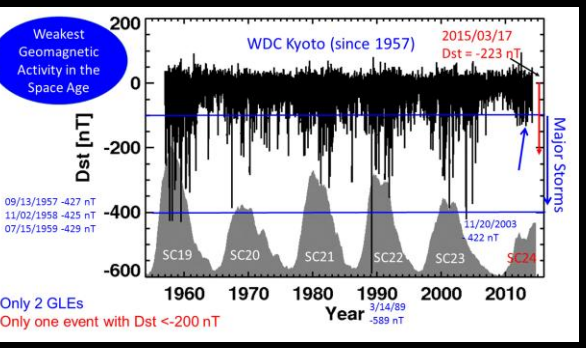
- Models of data assimilation effectiveness
- What is the minimum infrastructure?
- How can we assess and maintain system reliability

Heliophysics Mission Timeline 1995-2025

National Aeronautics and Space Administration



Heliophysics Science Highlights

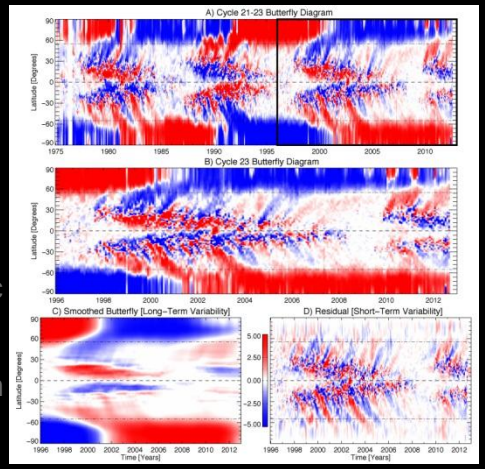


Unexpected consequences of a weak solar cycle:

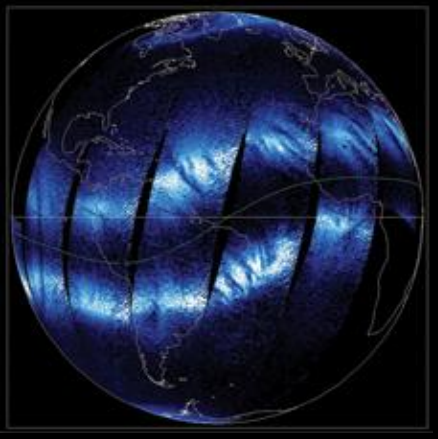
New research suggests that the weak solar activity leads to a feeble heliophere, which acts on CMEs to make them expand more. The expansion results in the dilution of B in the CME leading to weaker storms. The weaker ambient field reduces the efficiency of particle acceleration, so no GeV particles are produced. Both these aspects represent a mild space weather, a lot milder than what is indicated by sunspot number.

Space Weather Forecasting with a lead time of ~ months

The quasi –annual forcing of the sun's eruptive, radiative, and particulate output is shaped by the solar magnetic activity band interaction and instabilities . Evidence of cross hemispheric overlap strongly influencing short-term activity and flux emergence process.



Monitoring of small magnetic features at high latitudes allows assessment of where in a surge we are, in addition to the phasing of the surges between hemispheres. Surges driven by large-scale waves in solar convection zone (analogous to terrestrial Jet Stream?).

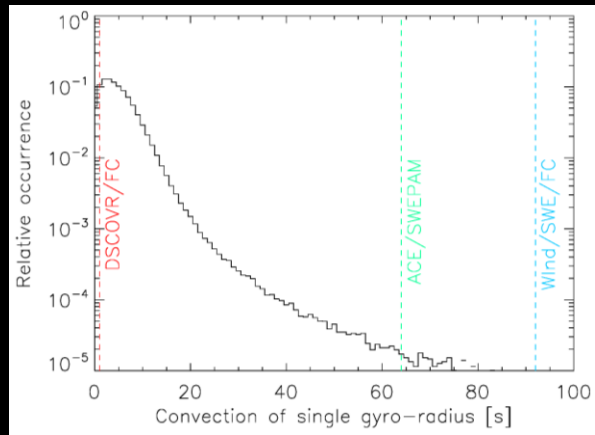


Study of Ionospheric 'Froth' May Improve GPS Communications:

A new study on irregularities in the ionosphere compares turbulence in the auroral region to that at higher latitudes, and provides insights that could have implications for the mitigation of this disturbance. The size of the irregularities in the plasma gives researchers clues about their cause, more turbulence means larger disturbances to radio signals.

DSCOVR opens a new window on kinetic physics of solar wind

Relative occurrence of the time in seconds for a single proton gyro-radius to convect past a spacecraft in the solar wind based on 20 years of Wind/SWE observations. Vertical lines indicate the time resolution of velocity distribution function measurements by DSCOVR, ACE/SWEPAM, and WIND/SWE



Space Weather Occurs at all Phases of the Solar Cycle...

Solar La Niña
(low sunspot number)

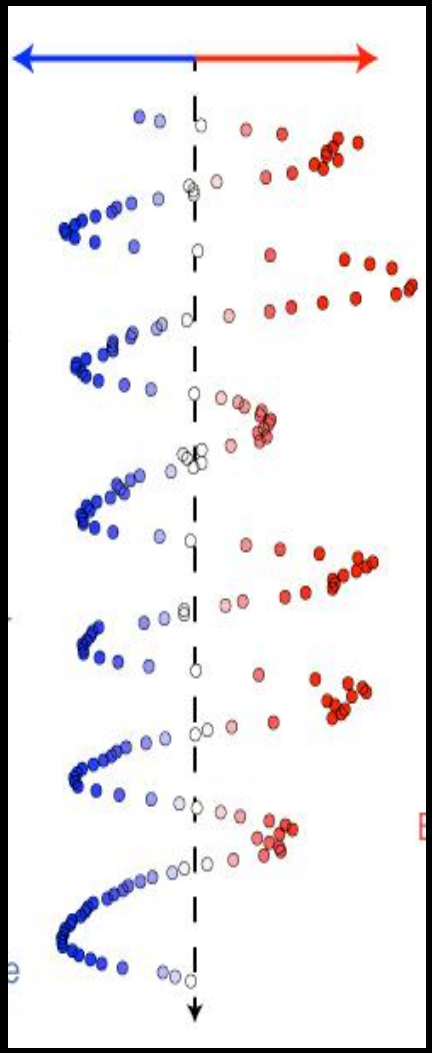
extreme galactic cosmic rays

rapid accumulation of space junk

sharp contraction of the heliosphere

collapse of the upper atmosphere

Total/spectral solar irradiance changes



Solar El Niño
(high sunspot number)

super solar flares

extreme solar “cosmic rays” (energetic particles)

radio blackouts

extreme geomagnetic storms

melted power grid transformers – power blackouts

solar wind streams hit Earth

HELIOPHYSICS ACCOMPLISHMENTS

Jack Eddy Postdoctoral Fellowship 2010-2015, 21 appointments

To train the next generation of researchers needed in the emerging field of heliophysics, in honor of the pioneering interdisciplinary researcher, Jack Eddy.

2015 Jack Eddy Fellowships

Elena Provornikova
PhD 2013 Solar Physics, Mechanics of Fluid, Gas and Plasma
Russian Academy of Science

Chao Yue
PhD 2015 Atmospheric and Ocean Sciences
University of California, Los Angeles

Bidya Binay Karak
PhD 2013 Physics
Indian Institute of Science, India

Chuanfei Dong
PhD (Student) Space Physics and Planetary Science
University of Michigan

LWS Institute

2015 Topic Areas

- Nowcasts of radiation storms (proton events) at energy levels that could create a radiation hazard for aircrew and passengers
- Nowcasts of atmospheric drag for LEO spacecraft
- Deadline 1 June 2015

2014 Topic Areas

Principles in relation to the effects of geomagnetically induced currents (GICs) during CME-driven geomagnetic disturbances (GMDs).

- 1st LWS Institute Working Group Meeting - 2-6 March 2015
- 2nd LWS Institute Working Group Meeting – October 2015

www.heliophysics.ucar.edu

Heliophysics Summer School Since 2007-2015, we have had:

Total Students ~280
International Students ~140
PhD Level ~230
Masters Level ~50

Heliophysics Summer School 2015

Seasons In Space: Cycles of variability of Sun-Planet systems

Heliophysics Textbooks

Heliophysics I:
"Plasma physics of the local cosmos"

Heliophysics II:
"Space storms and radiation: causes and effects"

Heliophysics III:
"Evolving solar activity and the climates of space and Earth"

Heliophysics IV: *(In preparation for publishing Summer 2015)*
"Active stars, their astrospheres, and impacts on planetary environments"

Heliophysics V: *(Online only – free access)*
"Space weather and society"

International Activities

Sponsored COSPAR/ILWS Roadmap:
Advancing space weather science to protect society's technological infrastructure (*published in Adv. in Sp.Res. with a summary article in Space Weather Journal in Spring, 2015)*

The Road Map prioritized those advances that can be made on short, intermediate and decadal time scales, identifying gaps and opportunities form a predominantly, but not exclusively, geocentric perspective.

UNCOPUOS Space Weather Agenda: Co-organized side meeting "Space Weather Services to Build Global Resilience" with NOAA/SWPC (Feb., 2015)

Sponsored: United Nations/Japan Workshop on Space Weather Workshop "Science and Data Ptoducts from ISWI Instruments" (March 2-6, 2015)

Organization of a week long COSPAR/ILWS/SCOSTEP-VarSITI Workshop:
ILWS workshop will merge with COSPAR/SWx and VarSITI to hold a workshop in Goa, India in 25-29th January, 2016 Announcement to come soon.

COSPAR/ILWS Symposium: On the margins of UNCOPUOUS (Feb., 2016) to promote the SWx roadmap.

MMS Launch

MMS Deployment

Heliophysics FY16 Overview

Favorable Budget: Showing first real growth in a Decade

($M)	2016	2017	2018	2019	2020
Heliophysics	$651	$685	$698	$708	$722

Meets our requirements - No surprises

Augmentation fully implements Decadal Survey (DS) DRIVE wedge

Provides requested resources for current program (zeroeth order recommendation of DS)

Where is the Heliophysics Division Going?

SMD Heliophysics Division Mission Statement (Why we exist… Not our Agency Objective):

Vision: Committed to creating a world in which our technological society benefits from understanding the sun, the space environment, and our place in the galaxy

Mission Statement: Empower the community to advance our understanding of Heliophysics and reap the benefits through science missions and enabling technology and research

Approach to implementing Decadal Survey recommendations

- Heliophysics Roadmap defines our detailed implementation plan for the Decadal Survey, including technology development requirements
- Perform on our commitments to complete the current program on time and on budget
  - President's FY16 budget supports Solar Probe Plus launch in 2018
- Strengthen our Research and Analysis, MO&DA, and Technology Programs
  - Work towards rebalancing research program (DRIVE) as recommended by the Decadal Survey
- Plan for more frequent, lower cost missions: Expand Explorers and Missions of Opportunity
  - CubeSat line started in FY14, next Heliophysics Explorer A/O likely in FY2016, STP in FY2017
- Commence development of the highest priority Strategic Program (STP, LWS) science targets, consistent with the budget and with Research and Explorer priorities

Continue to build our understanding of heliophysics (the sun and its interaction with the Earth and the solar system, including space weather

National Air and Space Museum Debuts Must-See Sun Video Wall

- Unveiled on March 18th, the 7 by 6 ft. Video Wall streams data from NASA's Solar Dynamics Observatory, or SDO.

- SDO takes ten images of the differing layers of the Sun's atmosphere every 12 seconds with an image size of 4096 x 4096 pixels. By comparison, a high-definition TV can only display 1920 x 1080 pixels.

- Tremendous computing power is required to visualize the data from SDO. This data is improving our understanding of the Sun's ever-changing magnetism.

- The Video Wall is located at the base of the Skylab exhibit in the Space Race Gallery.

Solar Probe Plus: Humanity's First Voyage to a Star